ANALYSIS OF MUSCLE ACTIVATION DURING SELECTED PLYOMETRIC EXERCISES ON LOWER EXTREMITY OF FOOTBALL PLAYERS

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SYNOPSIS

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Certificate

I hereby declare that the short synopsis "**Analysis of muscle activation during selected plyometric exercises o on lower extremity of football players**" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Physical education under the department of Sports Biomechanics of Lakshmibai National Institute of Physical Education, Gwalior during the academic year 2022-23.

It is a bonafide record of original work carried out under the supervision Prof. Jospeh Singh and has not been submitted in full or part to any other university or institute for a degree.

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Abstract

This study investigates the muscle activation patterns of the lower extremities during various plyometric exercises in male football players using surface electromyography (sEMG). Plyometric exercises are known to enhance explosive power, speed, agility, and overall athletic performance. Given football's dynamic demands, including sprinting, jumping, and rapid directional changes, understanding specific muscle recruitment during different plyometric drills can guide targeted training and injury prevention. The research aims to analyze both peak and average muscle activations in six key lower limb muscles (Rectus Femoris, Vastus Medialis, Biceps Femoris, Semitendinosus, Tibialis Anterior, and Gastrocnemius) across selected exercises, and to examine correlations with kinematic variables such as flight time, take-off velocity, and jump height. Thirty male inter-university football players (ages 18–25) participated in the study, performing a series of standardized plyometric movements while EMG data was recorded. Statistical analyses, including repeated measures ANOVA and correlation testing, were employed to assess muscle activity patterns. The outcomes are expected to contribute valuable insights for coaches, trainers, and sports therapists in optimizing performance programs, tailoring rehabilitation protocols, and reducing the risk of lower limb injuries in football players.

Chapter I

Introduction

Plyometrics is a form of exercise that focuses on explosive movements to improve muscular power and athletic performance. It involves rapid stretching and contracting of muscles, often through jumping and bounding exercises. Plyometrics aim to enhance speed, agility, and strength by increasing the efficiency of muscle contractions. All the exercises involved in plyometrics are characterized by lengthening and explosive contraction of the muscle group involved in the activity. The mechanism of plyometrics works in three phases 1) eccentric phase (lengthening of muscle) 2) Amortization (isometric phase) 3) concentric phase (shortening of muscle). The efficiency of these exercises are based on Stretch shortening cycle (SSC), that is transition of muscles from eccentric phase to concentric phase combined stretch reflex of muscles, when muscle spindle gets over stretched a reflex signal is sent to the spinal cord which cause spinal cord agonist muscle start working, preventing muscles from getting overstretched causing a quick and explosive contraction in the muscle. (Davies et al., 2015)

Importance in games and sports

All the games and sports require speed, agility, explosive movements and vertical jumping like spiking in volleyball, change of direction in football and sprinting in athletics where athletes need to generate force by hitting the ground with minimal ground contact time. And increasing demands of a good performance in sports the players need to remain fit and away from injuries. Studies have shown that plyometrics interventions can help improve speed, agility and jumping power in

athletes (Slimani et al., 2016). These training interventions can be used to enhance athletic performance, prevent athletes from injury and rehabilitation of the injuries.

Plyometrics exercises vary according to the need of the games and the part of the body which is needed to be train. Plyometrics for upper extremities consists of clap pushups, medicine ball chest passes, two hand side to side throws etc. And to improve athletic abilities of lower limbs plyometrics like depth jumps, vertical jumps, bounding, squat jumps etc can be used. These exercises thus improve muscle architecture, tendon stiffness and enhance physical performance (Ramírez-delaCruz et al., 2022).

Plyometrics involves recruitment of muscles and tendons; it is the combined activation of both muscle and tendon that help create an explosive movement. Some studies has shown recruitment of muscle groups of lower extremity like quadriceps and gastronemius (Ebben et al., 2008).

Plyometrics primarily target the muscles of the lower body, specifically the:

- Quadriceps: These are the muscles located on the front of the thigh and include the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius.
- Hamstrings: These muscles are situated on the back of the thigh and include the biceps femoris, semitendinosus, and semimembranosus.
- Gluteus group: The gluteal muscles, which consist of the gluteus maximus, gluteus medius, and gluteus minimus, are responsible for hip extension, abduction, and rotation.
- Calves: The calf muscles comprise the gastrocnemius and soleus muscles.

They are involved in ankle plantar flexion.

- Hip flexors: These muscles, including the iliopsoas and rectus femoris, are responsible for hip flexion movements.
- Core muscles: Plyometrics engage the core muscles, including the abdominals, obliques, and lower back muscles, to provide stability and control during explosive movements.

GAME SPECIFIC PLYOMETRIC USES

Football is an open ended game which requires both aerobic and anaerobic capacity. A game of 90 minutes requires dynamic movement like short bursts of sprints, continuous changing of direction, tackling, one leg dynamic balance, accelerating and decelerating, jumping for heading and landing on one leg or both. All these movement put continuous strain on lower extremity and chances of injuries increases with every movement. Some researchers have already proven that proven that plyometrics exercises can help improve agility, speed and explosive strength.(Bedoya et al., 2015)

Performing such varied movements must activate specific muscles within the same muscle groups as the movement demands a different in different actions.

Similarly plyometric exercises also come in variety of forms, and majority of them focus on the large muscle groups of lower extremities(Ebben et al., 2008).Considering and comparing the variety of games their dependence on explosive actions and parallelly the existence of the variety in plyometric exercises invoked a curiosity in the researcher to examine whether particular plyometric exercises activate particular muscles more and this fact can help modify the training regime accordingly.

ELECTROMYOGRAPHY (EMG)

EMG stands for Electromyography. It is a medical diagnostic technique used to evaluate and record the electrical activity produced by skeletal muscles. EMG can help diagnose muscle and nerve disorders by measuring the electrical signals generated by muscle fibers during rest and contraction. It is commonly used to assess conditions such as muscle weakness, nerve damage, and neuromuscular disorders. There are two main types of EMG (Electromyography):

Surface EMG (sEMG): In this type of EMG, electrodes are placed on the surface of the skin directly above the muscles being studied. The electrodes detect and record the electrical activity produced by the underlying muscles. Surface EMG is non-invasive and can provide information about overall muscle activity and coordination. It is commonly used in clinical settings for evaluating muscle function, identifying muscle imbalances, and assessing muscle recruitment patterns during movement.

Needle EMG (nEMG): Needle EMG involves the insertion of fine, disposable needle electrodes directly into the muscle being examined. The electrodes detect the electrical signals generated by individual muscle fibers. Needle EMG provides more detailed information about the electrical activity of specific muscles and can help identify abnormalities such as muscle damage, nerve dysfunction, or neuromuscular disorders. It is often used to diagnose conditions such as peripheral neuropathy, myopathy, and motor neuron diseases.

Due to the feasibility and less complexity in surface EMG, researcher will be using surface EMG for the study.

As the researcher wants to check activation of different muscles during a particular plyometric exercise. Surface EMG is most suitable equipment to check the muscle activation within the ethical boundaries of research.

Statement of the problem

Analysis of muscle activation during selected plyometric exercises on lower extremity in football players.

Research Question

- Is there any difference in the peak and average muscle activation during selected plyometric exercises on lower extremities in football players?
- Is there any relation between kinematic variables and muscles activation during different plyometric exercises?

Objectives of study

The objectives of the study are:

- To determine the peak muscle activation of each muscle during selected plyometric exercises on lower extremity in footballers.
- To determine the average muscle activation of each muscle during selected plyometric exercises on lower extremity in footballers.
- To find out if there is a relationship between kinematic variables and muscle activation.

Hypothesis

On the basis of literatures reviewed, available research findings, expert opinions and researcher's own understanding of the problem, it is hypothesized that:

H1: There will be significant difference in the peak muscle activation of selected muscles during selected plyometric exercise of lower extremity.

H2: There will be significant difference in the average muscle activation of selected muscles during selected plyometric exercise of lower extremity.

H3: There will be significant relationship between kinematic variables and muscle activation during selected plyometric exercises.

Delimitation

- The study will be delimited to 30 male players of LNIPE, Gwalior.
- The study will be delimited to football players.
- The study will be further delimited to players of age ranging between 18- 25 years.
- The study will be delimited to following muscles:

    i. Rectus femoris
    ii. Vastus medialis
    iii. Biceps femoris
    iv. semitendinosus
    v. Tibialis anterior
    vi. Gastronemius

Limitation

Researchers don't have control over lifestyle, habits, heredity, nutritional intake, and physical fitness level. These were considered as limiting factors of the study.

Definition and explanation of the terms

- Plyometrics – Exercises which contain lengthening of muscles followed by contraction of muscles to produce explosive movements.
- Amortization phase – It refers to a time interval between eccentric and concentric contraction of muscles. The shorter amortization phase is, the more explosive contraction of muscles will be.
- Stretch shortening cycle - SSC refers to the muscle action when active muscle lengthening is immediately followed by active muscle shortening.
- Electromyography - Electromyography is a technique for evaluating and recording the electrical activity produced by skeletal muscle.

SIGNIFICANCE OF THE STUDY

1. The results of present study will provide strong scientific knowledge to the coach, trainers and players which will help them in selecting plyometric exercises according to their need.
2. The results will help sports physiotherapists in making training regimes for rehabilitation.
3. The study will be a feedback mechanism and will add to the critical literature.

4. Findings of the study may be used for prevention of muscle related injuries.
5. This study may help to improve lower extremity force generation in football players.
6. This study may improve the heading technique performance in football players.

CHAPTER II

REVIEW OF RELAED LITERATURE

(Ebben et al., 2008) The aim of this study was to better understand the nature of plyometric workouts by examining the motor unit activation of the quadriceps (Q), hamstring (H), and gastrocnemius (G) muscle groups during a range of plyometric exercises.

The exercises included two-foot ankle hops, 15-cm cone hops, tuck, pike, and box jumps, one- and two-leg vertical jumps and reaches, squat jumps with roughly 30% of their 1RM squat load, and 30- and 61-cm depth jumps. Twenty-three athletes volunteered to participate in the experiment. One-way repeated-measures ANOVA was used to analyse the integrated electromyography data for each exercise.

Results: When all participants are analysed, as well as separately for men, women, subjects with vertical jumps greater than 50 cm, and individuals with vertical jumps less than or equal to 50 cm, the results showed significant main effects for the Q (p 0.05). In the examination of all individuals, men, and subjects with vertical leaps larger than 50 cm, significant main effects for the G muscle group were also discovered (p 0.05). For the H muscle group, there were no noteworthy major effects discovered. Plyometric exercises varied widely, as seen by pairwise comparisons.

(Ramírez-delaCruz et al., 2022) Determine the effects of PT on lower body muscle architecture, tendon structure, stiffness, and physical performance was the goal of this systematic review and meta-analysis.

Methods: The analysis covered five electronic databases. The following were

the requirements for inclusion: (1) English language accessibility; (2) experimental studies with PT of at least eight sessions; and (3) subjects who were healthy adults. Utilising Review Manager Software, four meta-analyses on muscle architecture, tendon structure, muscle and tendon stiffness, and physical performance were carried out.

As a result, 32 studies out of 1008 search results qualified for meta-analysis. A meta-analysis of muscle architecture revealed a slight effect of PT on pennation angle (SMD: 0.29; [95% Confidence Interval (CI) 0.02, 0.57]) and a moderate effect of PT on fascicle length (SMD: 0.51; [95% Confidence Interval (CI) 0.26, 0.76]). A moderate effect of PT on tendon stiffness was discovered by the meta-analysis (SMD: 0.55; [95% CI 0.28, 0.82]). The lower body physical performance meta-analysis found that PT had a moderate impact on strength and leaping (SMD: 0.57; [95% CI 0.42, 0.73]).

(Simenz et al., 2012) In order to determine the precise muscle training stimulus of each exercise variation, this study assessed the activation of the biceps femoris (BF), gluteus maximus (GMx), gluteus medius (GMe), rectus femoris, semitendinosus (ST), vastus lateralis, and vastus medialis during 4 variations of the step-up exercise. Step-ups, crossover step-ups, diagonal step-ups, and lateral step-ups were among the workouts.

Methods: On a 45.72-cm (18-in.) plyometric box, 15 women who regularly engage in lower body resistance training did the 4 exercises with 6 repetition maximum loads. A telemetered electromyography (EMG) system was used to capture the data, and root mean square values for the eccentric and concentric phases of the EMG were determined. Multiple differences in muscle activation between the

exercises were discovered by repeated-measures analysis of variance (p 0.05).

Results: The crossover step-up induced the most concentric muscle activation for the GMe, while the step-up elicited the most eccentric muscle activation for the GMe and the most concentric and eccentric muscle activation for the GMx, BF, and ST.

(Bedoya et al., 2015) Goal: To establish the impact of plyometric training on young football players' athletic performance, this systematic review critically analysed the literature.

Methods: Seven papers in all met the following requirements to be included in this review: football players aged between 12 and 17 competed in the studies, which (a) used plyometric training programmes to evaluate athletic performance and (b) were published between 2000 and January 2014. The PEDro scale, which has scores ranging from 4 to 6, was used to evaluate the study methodology.

Results: The methodology and procedures used by the included research varied and were similar. Because of plyometric training treatments, athletic performance, including kicking distance, speed, jumping ability, and agility, greatly increased. According to the available research, plyometric training should be performed during football practise two days a week for eight to ten weeks, with a 72-hour rest time in between. For this age range, the starting amount of foot interactions per session should be 50–60, increasing to no more than 80–120 foot contacts per session to avoid overuse issues. Per training session, 2-4 sets of 3–4 plyometric training activities should be completed for 6–15 repetitions.

Ana Filipa Silva et al. (2019) Goal: To examine how plyometric training affects volleyball players' performance.

Methods: For publications published no later than December 2018, a systematic search was carried out using PubMed, SciELO, SPORTDiscus, Medline, Scopus, Academic Search Complete, CINAHL, and Web Science in accordance with the PRISMA standards.

Results: Plyometric training interventions' primary tested ability of the vertical leap (15 studies), which was followed by strength (four studies), the horizontal jump (four studies), flexibility (four studies), and agility/speed (three studies). Additionally, it was shown that female athletes who were young (under 18) were the subjects of the most research. Plyometric training appears to improve volleyball players' vertical jump, strength, horizontal jump, flexibility, and agility/speed, according to the research that were reviewed.

(Sale, 1988) Strength performance depends not only on the volume and quality of the involved muscles, but also upon the capability of the nervous system to meet sparks the muscles. Strength training may begin adaptive changes within the nervous system that allow a trainee to further completely spark high carriers in specific movements and to more coordinate the activation of all applicable muscles, thereby effecting a lesser net force in the intended direction of movement. The substantiation indicating neural adaption is reviewed. Electromyography studies have handed the most direct substantiation. They've shown that increases in peak force and rate of force development are associated with increased activation of high transport muscles. Possible kickback acclimations related to high stretch loads in jumping and

rapid-fire complementary movements have also been revealed. Other studies, including those that demonstrate the “cross-training” effect and particularity of training, give farther substantiation of neural adaption. The possible mechanisms of neural adaption are in relation to motor unit recruitment and blasting patterns. The relative places of neural and muscular adaption in short- and long- term strength training are estimated.

(Simenz et al., 2012) The loaded step-up exercise allows strength and exertion interpreters to incorporate a unilateral resistance for athletes while performing extension at the hamstrings, knee, and plantar flexion at the ankle. This study estimated the activation of the biceps femoris(BF), gluteus maximus(GMx), gluteus medius(GMe), rectus femoris, semitendinosus(ST), vastus lateralis, and vastus medialis during 4 variations of the step-up exercise to assess the specific muscle training encouragement of each exercise variation. The exercises included the step-up, crossover step- up, slant step- up, and side step- up. Fifteen women who regularly engaged in lower body resistance training performed the 4 exercises with 6 reiteration maximum loads on a45.72- cm (18- in) plyometric box. Data were collected with a electromyography (EMG) system, and root mean square values were calculated for EMG data for eccentric and concentric phases. Results of a repeated- measures analysis of friction revealed a variety of differences in muscle activation between the exercises. The results indicated that the crossover step- up inspired the top most concentric muscle activation for the GMe, whereas the step- up inspired topmost eccentric activation for the GMe and topmost activation for the GMx, BF, and ST in both concentric and eccentric phases. These findings can be used by interpreters to inform exercise selection to stylish target and maximally spark a variety of musculature.

(Kossow & Ebben, 2018) Plyometric exercises are constantly performed as part of a strength and exertion program. Utmost studies assessed the kinetics of plyometric exercises primarily performed in the perpendicular plane

. The purpose of this study was to estimate the multiplanar kinetic characteristics of a variety of plyometric exercises, which have a significant vertical element. This study also sought to assess coitus differences in the intensity progression of these exercises. Ten men and 10 women served as subjects. The subjects performed a variety of plyometric exercises including the double- leg hop, standing long jump, single- leg standing long jump, bounding, skipping, power skipping, cone hops, and45.72- cm chain hops. Subjects also performed the countermovement jump for comparison. All plyometric exercises were estimated using a force platform. Dependent variables included the rate of force development and ground response forces for each exercise in the perpendicular, anterior, and sagittal planes

A 2- way mixed analysis of friction with repeated- measures for plyometric exercise type demonstrated main goods for exercise type for all dependent variables. There was no significant difference between plyometric exercise type and coitus for any of the variable assessed. These findings should be used to guide interpreters in the progression of plyometric exercise intensity, and therefore program design, for those who bear significant vertical power in their sport.

(Ebben et al., 2011) Quantification of plyometric exercise intensity is necessary to understand the characteristics of these exercises and the proper progression of this mode of exercise. The purpose of this study was to assess the kinetic characteristics of a variety of plyometric exercises. This study also sought to

assess gender differences in these variables. Twenty-six men and 23 women with previous experience in performing plyometric training served as subjects. The subjects performed a variety of plyometric exercises including line hops, 15.24-cm cone hops, squat jumps, tuck jumps, countermovement jumps (CMJs), loaded CMJs equal to 30% of 1 repetition maximum squat, depth jumps normalized to the subject's jump height (JH), and single leg jumps. All plyometric exercises were assessed with a force platform. Outcome variables associated with the takeoff, airborne, and landing phase of each plyometric exercise were evaluated. These variables included the peak vertical ground reaction force (GRF) during takeoff, the time to takeoff, flight time, JH, peak power, landing rate of force development, and peak vertical GRF during landing. A 2-way mixed analysis of variance with repeated measures for plyometric exercise type demonstrated main effects for exercise type and all outcome variables and for the interaction between gender and peak vertical GRF during takeoff . These findings can be used to guide the progression of plyometric training by incorporating exercises of increasing intensity over the course of a program.

Chapter III

Procedure

In this chapter, the selection of subjects, selection of variables, administration of tests, collection of data and statistical technique for analysis of data has been described.

Selection of subjects

30 male subjects will be purposively selected. 10 subjects from each game who has played inter university level from Lakshmibai university of physical education are selected.

Selection of variables

1) Peak rectified EMG of muscles.

- Rectus femoris
- Vastus medialis
- Biceps femoris
- Semitendinosus
- Tibialis anterior
- Gastrocnemius

2) Average rectified EMG of muscles.

- Rectus femoris
- Vastus medialis
- Biceps femoris
- Semitendinosus

- Tibialis anterior
- Gastrocnemius

3) Kinematic variables

- Flight time during jump
- Take off velocity
- Maximum jump height

Collection of data

SURFACE ELECTROMYOGRAPHY

This research study for analyzing the muscles activities apparatus used BTS FREEEMG 300 for surface E.M.G. recording because it is a non-invasive procedure for estimating electrical muscle activity during muscle relaxation and contraction periods. This procedure is the most widely recognized type of E.M.G. recording in most sports biomechanics situations – it includes the position of the electrodes or E.M.G. electrodes (two or more) on the site of placement of selected muscles on the subject's skin. The E.M.G. signal measurement technique is standardized and corresponds to the classical detection amplification of myoelectrical activity changes in the skeletal musculature. In surface electrodes positioned at the midpoint of the measured muscle at a standardized distance of 2 cm (Centre to center) along the muscular fibers.

Preparation of Skin – Removal of hairs and application of a 60-70% alcohol-based solution (isopropyl alcohol) on a single-use cotton-wool ball on the superficial surface skin for the purpose of disinfecting and better conductance of the skin

Administration of test

All the 30 participants will be given 15 minutes of warm up prior to final ups. Starting with general warm up exercises like jogging, dynamic stretching and some small sprints. After that specific warm up like squats and some jumping exercises to activate muscles and avoid injuries.

One familiarization session will be kept making participants ready for the movements to be performed.

After that a proper demonstration of plyometrics will be given with proper technique to avoid injuries and to attain proper data.

After that EMG electrodes will be placed on the muscle belly of the subjects and 3 trials of each jump will be recorded.

PROTOCOLS FOR JUMPS

- Squat jump- Start from a squat position angle of knee should be 90-degree, hand behind head. On the signal ‘go’ subject will jump as high as possible and will land back to squat position.
- Split squat jump- Start from a lunging position. On signal ‘go’ subject will jump with full force and land back in initial position.
- Box jump- A box of 24 inches will be used and the athlete will start from the ground and on signal ‘go’ athlete will jump upon the box.
- Depth jump- Subject will stand upon a box of 24 inches and on signal ‘go’ subject jump down and hold the squat position for 2 seconds.
- Vertical jumps – Subjects stands on a firm surface and on signal ‘go’ jump vertically upward to achieve maximum height.

- Single leg vertical jump – Subjects will stand on one foot and on signal ‘go’ jump vertically upward to achieve maximum height.
- Jump over barrier- Subject stands behind a hurdle and on signal ‘go’ will jump to cross the barrier.
- Counter movement jump- The subject will squat to their preferred depth and then jump as high as they can with hands on the waist.
- Counter movement ump with arm thrust- The subject will squat to their preferred depth and the jump as high as they can with full arm swing.

Statistical analysis

- In order to examine peak and average muscle activation among the muscles of selected plyometric exercises repeated measure ANOVA will be used since same participant will perform all the exercises in a crossover manner.
- In order to determine peak and average muscle activation for particular muscle ONE WAY ANOVA will be used.
- In order to check if there is any correlation between kinematic variables and muscles we will use multiple correlation.

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